Broadband Acoustic Clutter
and
Seabed Variability: its Influence on Prediction Uncertainty

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LONG TERM GOALS

The long term goals associated with these projects are to:

1) improve performance of low-mid frequency active sonar systems against clutter

2) assess and characterize uncertainty in the tactical naval environment.

OBJECTIVES

The objectives of the first project are to understand the mechanisms that lead to clutter and develop models that predict the temporal/spatial/frequency dependence of the observed clutter.

The objectives of the second project are to characterize the spatial variability of the seabed geoacoustic properties using acoustic methods and determine the uncertainties and errors associated with the estimation of the geoacoustic properties.

APPROACH

The FY05 approach was to isolate a clutter event in two ways:

1) measure clutter feature at close range, eliminating the uncerainties of the propagation to and from the feature and

2) examining methods (and their limitations) for removing propagation effects by obtaining the geoaoucstic properties via the diffuse reverberation.

For the second project, the main task in FY05 was to wrap-up both individual and team efforts which included completion of journal articles and ensuring that the survey community (NAVOCEANO) was apprised of the results from the Seabed Variability Team and the implications of those results.

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WORK COMPLETED

The efforts in FY05 were directed towards:

1) development of model to determine the limitations of geoacoustic inversion via reverberation, and

2) exploitation of model/theory to determine the minimum amount of information to unambiguously determine the geoacoustic properties.

Both of these were done for a simple Pekeris waveguide, though some of the results are applicable to wide range of realistic environments. Also in FY05, there was a considerable data analysis effort (from Boundary04 and earlier experiments) for clutter features, developing analysis methods for both long-range and short-range observations.

The Seabed Variability Program was successfully concluded with more than 30 peer reviewed publications as well as numerous reports and articles in conference proceedings. The key team results were briefed to the survey community.

RESULTS

Examination of methods for extracting geoacoustic properties from reverberation.

Long-range reverberation in shallow-water is sensitive to the properties of the seabed as well as the ocean volume and sea surface. In some environments, reverberation from the seabed may dominate the overall observed reverberation. Reverberation in such instances provides an attractive way to rapidly probe seabed properties. Numerous techniques have been developed that invert the seabed properties from the reverberation, however, a characteristic of almost all these approaches is that the scattering law is assumed *a priori*.

What are the errors associated with picking the incorrect scattering kernel? This is one of the questions that we sought to answer. In a Pekeris waveguide, the errors were quantified for a) the Urick (or sonar equation) method in which both the propagation and the reverberation are measured and b) the common "reverberation inversion" method where only the reverberation is measured. As one example, if the Urick method is used but the scattering actually follows the Lommel-Seeliger Law μ_{L-S} the resulting errors in the scattering strength μ can be written:

$$\mu_{L-S} \cong \mu_{Urick} \frac{4}{\varepsilon} \sqrt{\frac{\pi \alpha r}{2H}} \frac{\mathrm{erf}\left(\sqrt{\alpha r \theta_c^2 / 2H}\right)}{1 - \exp\left(-\alpha r \theta_c^2 / 2H\right)} \tag{1}$$

where r is range H is water depth ,θ_χ is the critical angle and α is the slope of the plane wave intensity reflection coefficient, R, where below the critical angle, $R \sim exp(-\alpha\theta)$ (sometimes called the Weston α). Examining Eq (1) shows that the error in choosing the wrong scattering kernel (for the sonar equation or Urick approach, the scattering kernel is independent of incident and scattered angle) is a function of both range and frequency (in natural seabed environments α is a function of frequency). The importance is that the errors in estimating the scattering strength from these methods can be quite large (see Figure 1). A more complete discussion can be found in Ref [1].

An alternative approach to using reverberation data to obtain geoacoustic properties from reverberation was explored in [2] exploring a new concept of a scaled reverberation ratio, *Γ*. Figure 2 shows raw reverberation data from the Malta Plateau alongside the scaled reverberation ratio; in the latter, scattering from the Ragusa Ridge is clearly visible as well as 3 clutter features (in this case wrecks). This quantity is expected to be very useful in studying clutter from a variety of anthropogenic as well as natural features.

Direct path (close-range) scattering measurements from a clutter feature

Using a vertical source and receive array, direct-path measurements were made over a mud volcano (dimensions of ~100mx60x5m) in order to determine the frequency/temporal and angular dependencies of the scattering. The measurements included both mono-static and bi-static scattering with incident angles of 3-5° and scattered angles from at 5° and 45°. The results showed target strengths of 6-12 dB with no significant dependence on vertically bi-static angle (although the range of bi-static angles was limited). There were no significant temporal variations observed (although the measurement period was quite short) and episodic events are quite possible which may lead to a change of scatter mechanism, e.g., scattering from bubbles instead of scattering from the structure itself which seems to be the likely mechanism under "steady-state" conditions. The scattering strength is large enough so that this feature may be a potential clutter feature. A first-order model of the scattering using a viscoelastic sphere gives reasonable results for both the monostatic and bi-static dependence (see Figure 3).

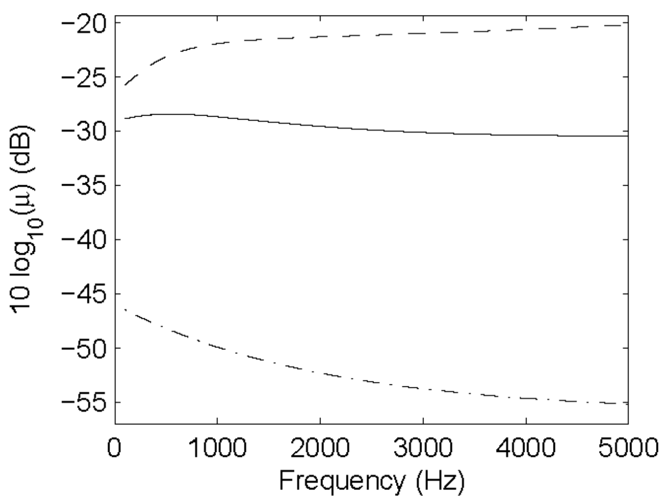

Figure 1. The scattering coefficient for reverberation at a fixed range (5 km) showing biases associated with an incorrect assumption of the scattering law.. If the true scattering strength followed Lommel-Seeliger Law (solid line), then the biased estimated assuming Urick approach would be the chain dashed line. The biased estimate assuming Lambert's Law would be given by the dashed line.

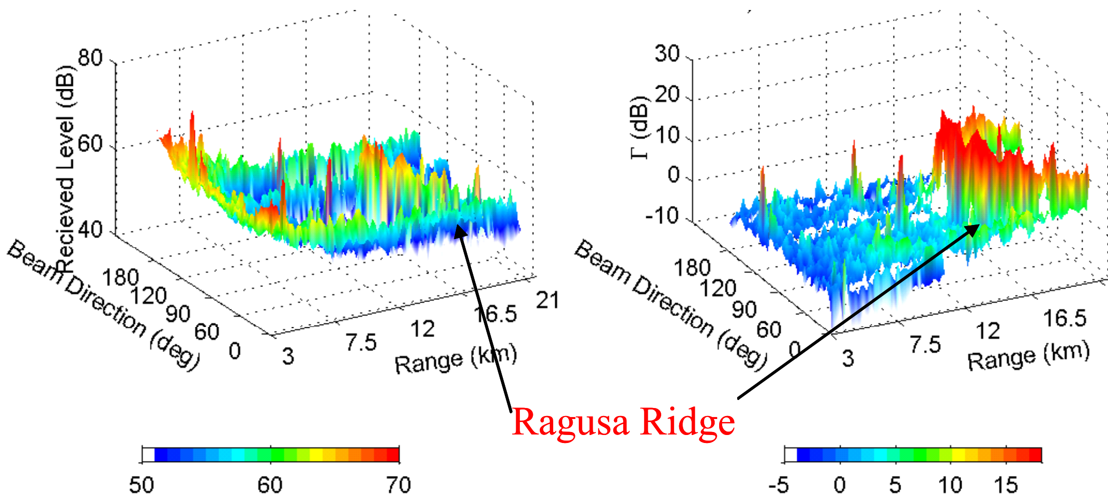

Figure 2. 800 Hz reverberation: a) received level, b) scaled reverberation ratio Γ.

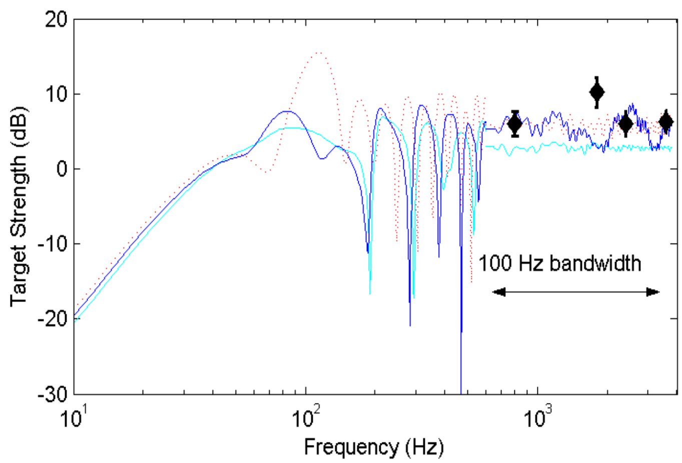

Figure 3.Measured data (♦) with 1 standard deviation along with model predictions of scattering from a viscoelastic sphere of radius 5m. Monostatic predictions (— / —) with properties of c_p=2200 / 4000 m/s c_s=1000 / 1800 m/s, α_p=0.1 / 0.02 dB/m/kHz; α_s=20 / 0.3 dB/m/kHz, ρ=2.2 g/cc respectively. Also shown are bi-static scattering predictions (—) with the same properties as (—)

IMPACT/APPLICATIONS

The importance of these results are that they

1) help quantify uncertainties and errors in estimating characteristics of sonar clutter,

2) will lead to the ability to separate clutter from the diffuse reverberation and the background geoacoustic properties and

3) will lead to clutter models that can be eventually used in signal processing algorithms to predict and then reduce the impact of clutter. Some of the techniques may have a significant impact on the survey community in terms of tools and strategies.

RELATED PROJECTS

Boundary Characterization Joint Research Project ONR-NATO SACLANT Centre: Providing acoustic, geoacoustic geologic, and geophysical data in the Straits of Sicily (2001-2005).

Broadband Clutter Initiative Joint Research Project ONR-NATO SACLANT Centre: this project has goals that are very closely with the above project. (2006-2009).

ONR STTR Advanced Physics-Based Modeling of Discrete Clutter and Diffuse Reverberation in the Littoral Environment (2005-2006).

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